

# PATENT SPECIFICATION

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## (54) IMPROVEMENTS IN OR RELATING TO TREATING MATERIALS WITH ULTRAVIOLET RADIATION

(71) We, THE ELECTRICITY COUNCIL, a British Body Corporate, of 30 Millbank, London SW1P 4RD, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the production of ultraviolet radiation and more particularly to the treatment of materials by irradiation with such radiation.

In our co-pending British Patent Application No. 32593/73 (Serial No. 1437796) we describe a method of, and an apparatus for treatment of a material by irradiation with ultraviolet radiation which is generated by a spark discharge at least a part of which is submerged in a preselected liquid, any remaining part being along the surface of the liquid. As is explained therein, the presence of the liquid around the submerged discharge prevents the hot plasma of the discharge region from expanding freely and as a consequence the plasma can attain a high temperature and pressure with the resultant emission of ultraviolet radiation.

We have now found that when expanding plasma is surrounded by liquid the resultant spectral emission of ultraviolet radiation is predominantly at a very short wavelength and is thus not suitable for treating liquids for bacteriocidal or biological purposes for which the radiation is required to be in a narrow spectral region at approximately 250 nm wavelength.

According to one aspect of this invention there is provided a method of producing ultraviolet radiation comprising the steps of effecting a spark discharge between two electrodes, and arranging for substantially the whole of the spark discharge path to be along the surface of a preselected liquid.

It will be understood that the term spark discharge used herein means a short duration disruptive discharge.

When a spark discharge occurs across the surface of a liquid, the plasma is not so severely confined as when the discharge path is surrounded by the liquid and the plasma does not attain such a high temperature and pressure and the resulting spectral emission is more useful in the treatment of liquids by ultraviolet radiation.

According to another aspect of this invention there is provided a method of treating a material by irradiation with ultraviolet radiation, comprising the steps of producing a spark discharge between two electrodes substantially the whole of the path of which discharge is along the surface of a preselected liquid, and exposing material to be treated to the ultra-violet radiation produced by the spark discharge.

The material to be treated may be stationary during exposure to the ultraviolet radiation, providing batch-type treatment, or the material may be continuously moved through a region of exposure to the ultraviolet radiation, thus providing a continuous treatment. It will be understood that the maximum speed of the material for 100% treatment will depend upon the repetition rate of the spark discharges. If required, the speed of the material may be arranged such that each elemental portion of the material is exposed to radiation from two or more spark discharges.

Where the material to be treated is a non-liquid for example a cloth which is to be made sterile, then preferably, the spark discharge is produced within a discharge chamber at least a portion of which is transmissive at the wavelengths of radiation required for the treatment, for example the aforementioned spectral region at approximately 250 nm.

In the case where the material to be treated is a liquid, the spark discharge may be arranged to occur along a surface of the liquid to be treated. The radiation from the plasma of ionised liquid vapour is not confined to discrete wavelengths, but is rather in the form of a continuum of energy distribution. Thus, given appropriate conditions of temperature and pressure a desired ultraviolet radiation can be obtained by the use of any liquid. However, it will be appreciated that certain liquids will be unsuitable for this purpose by virtue of their reaction to the ultraviolet radiation resulting in a physical and/or chemical change in the liquid. An example of an unsuitable liquid would be an oil which undergoes a cracking process when irradiated by ultraviolet light, or as a result of the conditions in the plasma.

A liquid to be treated may be introduced into the interior of the discharge chamber where it will undergo treatment, and in this case it will not be necessary to make a portion of the discharge chamber transmissive to the ultraviolet radiation. The size of the discharge chamber will depend upon the intensity of the ultraviolet radiation generated and also upon the degree of absorption of ultraviolet radiation in the material to be treated, and will be selected such that a satisfactory treatment of the liquid is obtained even at the greatest penetration of the ultraviolet radiation, i.e. at the inner peripheral surface of the discharge chamber.

The invention further envisages an apparatus for producing ultraviolet radiation comprising two electrodes spaced apart in a discharge chamber, means arranged to supply a preselected liquid to the discharge chamber such that a surface of the preselected liquid is simultaneously in contact with both electrodes and means arranged to apply across the electrodes a voltage which is sufficiently high that a spark discharge occurs between the electrodes along the surface of the liquid.

This apparatus may be employed in an apparatus for treating a material by irradiation with ultraviolet radiation which apparatus for treating further comprises means arranged for exposing the material to be treated to the ultraviolet radiation produced by the spark discharge.

Preferably, the discharge chamber is cylindrical and is arranged with its axis approximately vertical. An electrode may be mounted on axis in respective upper and lower closure members of the discharge chamber. In the case where a closure member is formed of a conductive material, the associated electrode will be insulated from the closure member. However, in the case where a closure member

is formed of an insulative material this is not necessary and the associated electrode may be permitted to contact directly the closure member.

Preferably, the liquid is arranged to have a vortical motion within the cylindrical discharge chamber, and this may be achieved by introducing the liquid substantially tangentially to the cylindrical wall of the chamber and removing the liquid from the chamber in a similar manner. Preferably, the liquid is introduced near the upper closure member and is removed from a point near the lower closure member. By creating this vortical motion of the liquid, substantially the whole of the liquid travels along an approximately helical path between the inlet and outlet points resulting in a substantially uniform treatment of the liquid.

The vortical motion of the liquid is also utilised to create an axial liquid-free volume between the electrodes. In one arrangement where the spark discharge path is to occur across the surface of the actual liquid being treated, the electrodes and the vortical motion are so selected that both the lower and the upper electrodes are in contact with the surface of the liquid defining or bounding the aforementioned axial volume. In an alternative arrangement the spark discharge is not to occur across the surface of the liquid to be treated and so in this case the electrodes and the vortical motion are arranged such that the surface of the liquid bounding the axial volume does not contact either of the electrodes. In this latter arrangement the lower electrode may have a passage formed therethrough, preferably funnel shaped, for receiving a column of liquid issuing from the upper electrode. The spark discharge will occur along the surface of the column of liquid, which is preferably water, passing between the electrodes. This latter arrangement has an advantage that any particles of metal eroded from the electrodes will tend to be swept into the lower electrode and carried away by an outlet system associated therewith. With the spark discharge occurring on the surface of the water column and not within the body of the column it is less likely that droplets from the column will be flung or ejected by the force of the expanding plasma into the liquid being treated. There will be a small amount of contamination of the liquid being treated due to this mechanism but it can be arranged by a suitable choice of the relative flow rates that this contamination is kept below a preselected maximum value. It will be appreciated that the droplets from the column will themselves be treated by the ultraviolet radiation and the con-

tamination referred to is physical or chemical rather than biological or bacteriological.

The electrodes may be mounted in the closure members in such a manner as to facilitate axial adjustment of the electrode within the discharge chamber i.e. electrode penetration depth. Means may be provided for adjusting the relative positions of the electrodes in response to detected characteristics of the spark discharge.

Specific embodiment of the invention will now be described with reference to the accompanying drawings in which:—

Figure 1 is a schematic longitudinal section of a discharge chamber for the treatment of a liquid;

Figure 2 is a schematic longitudinal section of an alternative form of the discharge chamber of Figure 1; and

Figure 3 is a scrap section showing a modified liquid inlet.

In Figure 1 a discharge chamber comprises a hollow cylindrical portion 10 arranged with its axis approximately vertical, and enclosed at its lower end by a closure member in the form of a flat plate 11 and at its upper end by a closure member in the form of a flat plate 12, of electrically insulative material, for example, polyethylene. The height of the chamber is approximately equal to its diameter, and is in the range 20 to 50 centimeters. The cylindrical portion 10 and the closure member 11 are formed of a material which is immune to chemical or electrochemical attack by a liquid to be treated, and also where the treatment forms a stage of an industrial process, for example a foodstuff preparation, the material will also be selected having regard to the particular industrial process. Where the liquid is water to be sterilised for use in foodstuff processing, the cylindrical portion 10 and closure member 11 are preferably formed of stainless steel.

An electrode assembly 13 is mounted in the centre of closure member 11 and comprises a solid cylindrical stainless steel electrode 14 having an integral enlarged conical head portion 15. The electrode 14 is threaded along its length and is screwed into an insulating sleeve 16 of approximately the same external diameter as that of the conical head portion 15. The sleeve 16 is formed of a phenolic laminate. The upper electrode 17 is in the form of a circular disc of stainless steel mounted on the internal surface of closure member 12 by means of a stud arrangement 18. The stud 18 and the electrode 14 are connected to a suitable electrical circuit (not shown) such as that disclosed in our co-pending application in order to produce spark discharges at a preselected repetition rate.

For optimising conditions of the treatment it may be desired to adjust the discharge repetition rate in order to suit the required liquid flow rate.

The liquid to be treated is introduced via inlet duct or pipe 19 which is substantially tangential to the cylindrical portion 10 and terminates thereat in an inlet port 20 adjacent the closure member 12. A corresponding arrangement comprising outlet duct or pipe 21 and outlet port 22 for removing treated liquid is provided adjacent closure member 11. If required the direction of flow of the liquid may be reversed, the liquid being introduced via pipe 21 and removed via pipe 19.

The tangential inlet and outlet arrangement results in a vortical motion of the liquid within the discharge chamber, and the liquid flow rate is chosen such that the liquid is in the form of a revolving annulus having an internal axial volume 23 which is filled by a gas. The internal surface 24 of the annulus of liquid terminates at the electrode 17 at its upper end and at the conical head portion 15 at its lower end. The gas in the axial volume 23 is conveniently air or nitrogen. The radial thickness of the annulus of liquid being treated will depend upon the pressure of the gas in volume at 23. The axial volume 23 communicates via a passage (not shown) through electrode 17 and closure member 12 with a pressure controlling means (not shown) which is arranged to control the gas pressure in dependence on the discharge parameters. The configuration of the axial volume 23 will also depend upon the water flow rate, and water control means (not shown) may be provided to control the vortical motion in dependence on the discharge parameters. The gas pressure control means and the water control means may be made interdependent, and may be interdependently controlled by means of a suitable system, known per se, for fluid flow or pressure control.

The gas within the axial volume 23 is not restricted to air or nitrogen, and will be selected in accordance with the nature of the liquid to be treated.

The expanding plasma in the discharge region is only partially confined or restricted where the discharge is across the liquid surface and we have found that the temperature in such a discharge region is in the region of 12,500°K which results in an ultraviolet emission in the region of 250 nm.

Figure 2 shows a modified arrangement of the discharge chamber for Figure 1, in which the upper electrode 17 is replaced by an electrode assembly 25 similar to electrode assembly 13 shown in Figure 1 but having an axial bore through which a

liquid, conveniently water, is introduced into the axial volume 23. The liquid emerges from electrode assembly 25 and falls as a column 26 towards a lower electrode assembly 27 which replaces the electrode assembly 13 of Figure 1. Electrode assembly 27 comprises a sleeve 28 functionally similar to sleeve 16 in Figure 1, into which is screwed a hollow pipe 29 having an enlarged annular head portion 30 whose internal surface is conical and which thus acts as a funnel to collect the column of liquid 26. Pipe 29 is made of a conductive material and is connected to the discharge circuit (not shown) whereby a spark discharge can be caused to occur down the length of the liquid column 26. Electrode assemblies 25 and 27 are mounted in closure members 12 and 11, respectively, such that their axial spacing may be adjusted, this adjustment being carried out automatically by means (not shown) responsive to the discharge parameters in order to compensate, for example, for the effects of wear and erosion of the conductive components of the electrode assemblies.

The funnel action of the lower electrode assembly in Figure 2 enables most, if not all, of the eroded material from either electrode assembly to be carried out of the discharge chamber through the bore in pipe 29, this reducing the risk of contamination of the liquid being treated.

In the discharge chamber of Figure 2 a passage for the introduction of gas to the axial volume 23, may be provided in either electrode assembly or in either of the closure members 11, 12.

As an alternative to introducing and removing the liquid being treated via pipes 19 and 21 respectively, the liquid may be introduced and removed via passages provided in the closure members. Figure 3 shows a scrap section of closure member 12a having therein a bore 31 at an acute angle to the plane of the closure member. An inlet duct or pipe 32 communicates with bore 31. It is appreciated that this inlet arrangement would be disposed in an outer region of the closure member and at such an angle so as to induce the required vortical motion of the liquid. A complementary arrangement would be provided in other closure member for extraction of the liquid.

It will be appreciated that for a given intensity of generated ultraviolet radiation optimum processing conditions will exist when the annular thickness of the liquid is such that the intensity of radiation reaching the outer regions of the annulus is just sufficient for the purposes of the treatment.

As an example of the use of the method of treatment, the treated liquid may itself

be water intended for human consumption, either directly or as a component of subsequently or previously processed foodstuffs. In this case the optimum depth of water to be treated, for example sterilised, will be in the region of a few tens of centimetres depending on the absorption properties of the particular sample of water in the wavelength region appropriate to the treatment, which in the case of bacteriocidal or other biological action, is preferably a spectral region extending for approximately 10 nm either side of 254 nm wavelength.

Whereas in the aforescribed electrode assembly 13 electrode 14 is formed of stainless steel and sleeve 16 is formed of a phenolic laminate, it will be appreciated that the choice of such materials will depend on the particular treatment being performed and the permissible contamination by material from the electrode assembly. For example, in make-up water for foodstuffs up to, say, 7 ppm of iron may be tolerated, but even traces of chromium or nickel would be impermissible. Thus, in this case electrode 14 should not be formed of stainless steel, but may be formed of mild steel instead. Similarly, in this case the introduction of phenols into the heated liquid would not be permissible, and so sleeve 16 may be formed of polyethylene instead. It will also be appreciated that other treatments may require other materials for the electrode and the sleeve.

#### WHAT WE CLAIM IS:—

1. A method of producing ultraviolet radiation comprising the steps of effecting a spark discharge between two electrodes, and arranging for substantially the whole of the spark discharge path to be along the surface of a preselected liquid.

2. A method of treating a material by irradiation with ultraviolet radiation, comprising the steps of producing a spark discharge between two electrodes substantially the whole of the path of which discharge is along the surface of a preselected liquid; and exposing material to be treated to the ultraviolet radiation produced by the spark discharge.

3. A method as claimed in claim 2 wherein the material to be treated is continuously moved through a region of exposure to the ultraviolet radiation.

4. A method as claimed in claim 3 wherein the spark discharge occurs repetitively and the speed of movement of the material through the region is arranged such that each elemental portion of the material is exposed to radiation from two or more spark discharges.

5. A method as claimed in any of claims 2 to 4 and for treating a non-liquid

material wherein the spark discharge is produced within a discharge chamber at least a portion of which is transmissive at the wavelengths of radiation required for the treatment.

6. A method as claimed in any of claims 2 to 4 and for treating a liquid, wherein the discharge is produced within a discharge chamber and the liquid to be treated is introduced into the interior of the chamber.

7. A method as claimed in claim 6 wherein the discharge is arranged to occur along a surface of the liquid to be treated.

8. A method as claimed in claim 6 or claim 7 wherein the discharge chamber is cylindrical and arranged with its axis substantially vertical and the electrodes are vertically spaced along said axis and wherein the liquid to be treated is arranged to have a vortical motion within the cylindrical discharge chamber, creating an axial liquid-free volume between the electrodes, by introducing the liquid substantially tangentially to the cylindrical wall of the chamber and removing the liquid from the chamber in a similar manner.

9. A method as claimed in claim 8 wherein the liquid is introduced near the top of the chamber and is removed from a point near the bottom of the chamber.

10. A method as claimed in either of claims 8 or 9, when claim 8 is dependant or claim 7, wherein the electrodes and the vortical motion are selected so that both the lower and the upper electrodes are in contact with the surface of the liquid defining or bounding the aforementioned axial volume.

11. A method as claimed in either of claims 8 or 9, when claim 8 is dependant on claim 6 and where the spark discharge is not to occur across the surface of the liquid to be treated, wherein the electrodes and the vortical motion are arranged such that the surface of the liquid bounding the axial volume does not contact either of the electrodes.

12. A method as claimed in claim 11 wherein the spark discharge is arranged to occur on the surface of a column of liquid issuing from the upper electrode and being received in a passage in the lower electrode.

13. A method as claimed in any of claims 8 to 12, wherein the configuration of the axial volume is controlled by interdependently controlling the flow rate of the liquid to be treated through the chamber and the pressure of a gas filling the axial volume.

14. An apparatus for producing ultraviolet radiation comprising two electrodes spaced apart in a discharge chamber, means arranged to supply a pre-

selected liquid to the discharge chamber such that a surface of the preselected liquid is simultaneously in contact with both electrodes and means arranged to apply across the electrodes a voltage which is sufficiently high that a spark discharge occurs between the electrodes along the surface of the liquid.

15. An apparatus for treating a material by irradiation with ultraviolet radiation comprising apparatus for producing ultraviolet radiation as claimed in claim 14 and further comprising means arranged for exposing the material to be treated to the ultraviolet radiation produced by the spark discharge.

16. An apparatus as claimed in claim 15 wherein the means to supply a voltage across the electrodes is arranged so that the discharge occurs repetitively and the means for exposing the material to be treated are effective to move the material continuously through a region of exposure to the ultraviolet radiation at a speed such that each elemental portion of the material is exposed to radiation from two or more spark discharges.

17. An apparatus is claimed in either of claims 15 or 16 and for treating a non-liquid material, wherein the discharge chamber has at least a portion which is transmissive at the wavelengths of radiation required for the treatment.

18. An apparatus as claimed in either of claims 15 or 16 and for treating a liquid, wherein said means for exposing include means for introducing the liquid to be treated to the interior of the discharge chamber.

19. An apparatus as claimed in claim 18 wherein the discharge chamber is cylindrical and arranged with its axis substantially vertical and the electrodes are vertically spaced along said axis and wherein said means for exposing include an inlet duct for introducing the liquid to be treated to the chamber, an outlet duct for removing said liquid, both inlet and outlet ducts being angled to promote an circulatory movement of said liquid in the chamber, and means for controlling the flow rate of said liquid through the chamber so that said liquid in the chamber has a vortical motion and forms a revolving annulus with an internal gas-filled volume.

20. An apparatus as claimed in claim 19 wherein the inlet duct and the outlet duct are disposed in the cylindrical wall of the chamber respectively to introduce and remove said liquid substantially tangentially to said wall.

21. An apparatus as claimed in either claim 19 or claim 20, wherein the inlet duct is near the top of the chamber and the outlet duct is near the bottom of the chamber.

22. An apparatus as claimed in claim 19 wherein the inlet duct and the outlet duct are respectively disposed in a top end closure member and a bottom end closure member of the chamber, so as to be at an acute angle to the plane of the respective closure member.

23. An apparatus as claimed in any of claims 19 to 22 wherein means are provided for controlling the pressure of the gas in said axial volume.

24. An apparatus as claimed in claim 23 wherein the shape of the electrodes, the flow rate controlling means and the gas pressure controlling means are all arranged such that, in use, the two electrodes are both in contact with the liquid surface which bounds said axial volume, so that the spark discharge occurs along said surface, the liquid to be treated constituting said preselected liquid.

25. An apparatus as claimed in claim 24 wherein the lower electrode comprises a conducting rod extending upwardly through a bottom end closure member of the cylindrical chamber and having an upwardly pointing conical head portion, and the upper electrode comprises a circular disc mounted axially on the internal surface of a top end closure member of the chamber.

26. An apparatus as claimed in claim 24 wherein the shape of the electrodes, the flow rate control means and the gas pressure control means are all arranged such that in use, the liquid surface bounding said axial volume does not contact either electrode, separate means to supply said

preselected liquid being provided.

27. An apparatus as claimed in claim 26 wherein the upper electrode comprises a conductive rod extending downwardly through a top end closure member of the discharge chamber and having an axial bore for the introduction of said preselected liquid to the chamber and the lower electrode comprises a hollow conductive pipe extending upwardly through a bottom end closure member of the chamber and having a head portion with a downwardly pointing conical internal surface forming a funnel, there being further provided means for supplying said preselected liquid to the bore in the upper electrode to form a column of said preselected liquid emerging from said upper electrode and falling for collection in the funnel formed by the head portion of the bottom electrode.

28. A method of treating a liquid substantially as hereinbefore described with reference to Figure 1 or Figure 2, of the accompanying drawings.

29. An apparatus for treating a liquid substantially as hereinbefore described with reference to Figure 1 or Figure 2 or Figure 1 or Figure 2 as modified in Figure 3 of the accompanying drawings.

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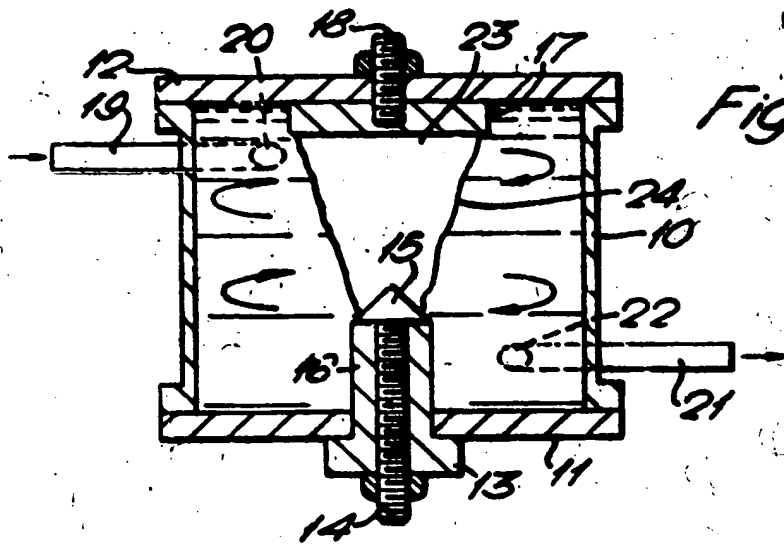


Fig. 1.

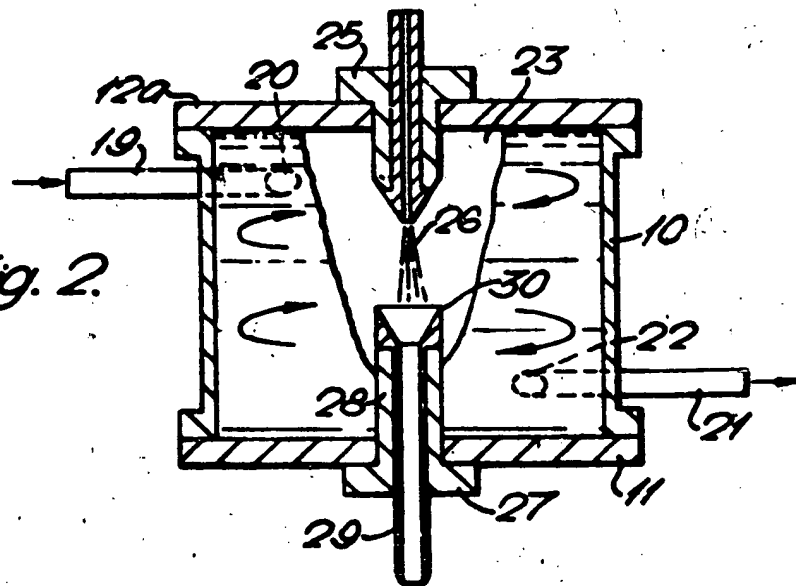


Fig. 2.

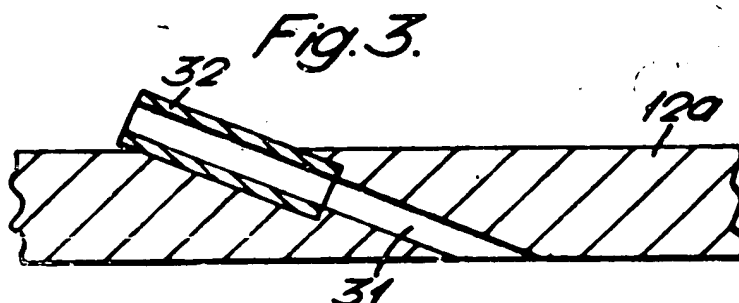


Fig. 3.

